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(54) Device for transporting thermal energy

(57) A heat transporting device comprises a sealed tube (1) containing a working medium. In use of the device, this medium evaporates at a place of a higher temperature, here called the heating zone, and condenses at a place of a lower temperature, here called the cooling zone. The resulting condensate returns to the heating zone. The tube is so shaped, e.g. with a spiral or meander configuration, that, in respect of successive portions of its length, the tube comprises a plurality of portions (3) that extend through the heating zone and a plurality of portions (4) that extend through the cooling zone. The present device has the advantage that it can be remarkably simple to produce. The device may be used for cooling electronic components (7), e.g. thyristors, or for cooling the coolant of an engine.

FIG.3.

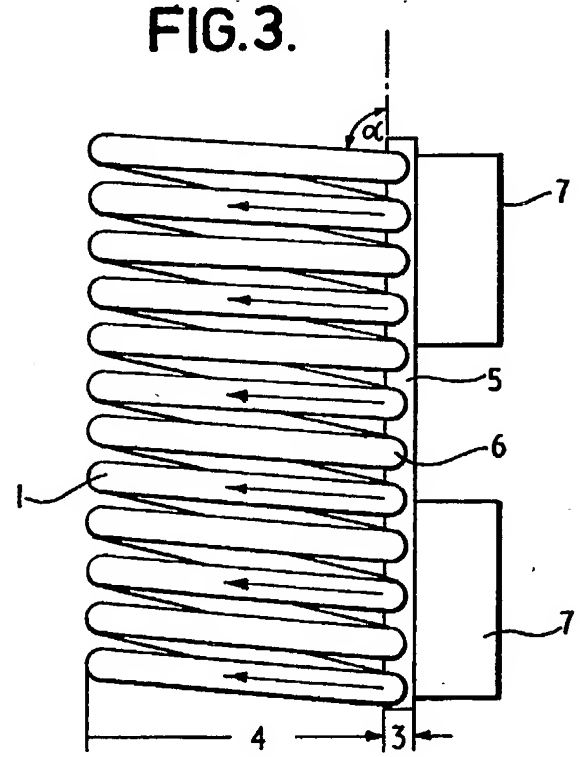

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FIG.1.

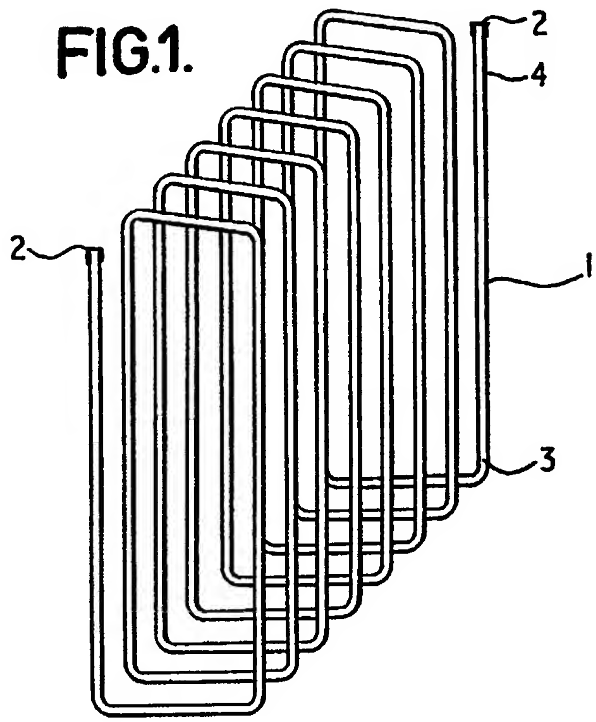


FIG.2.

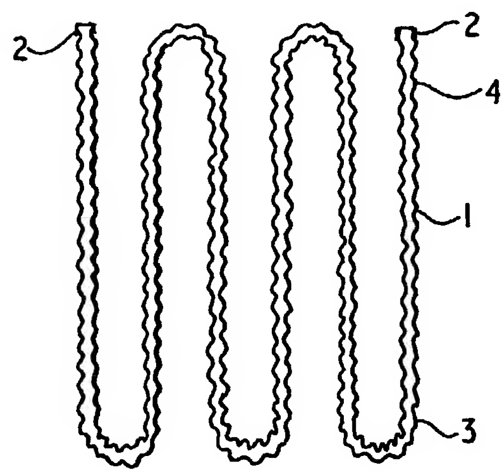


FIG.3.

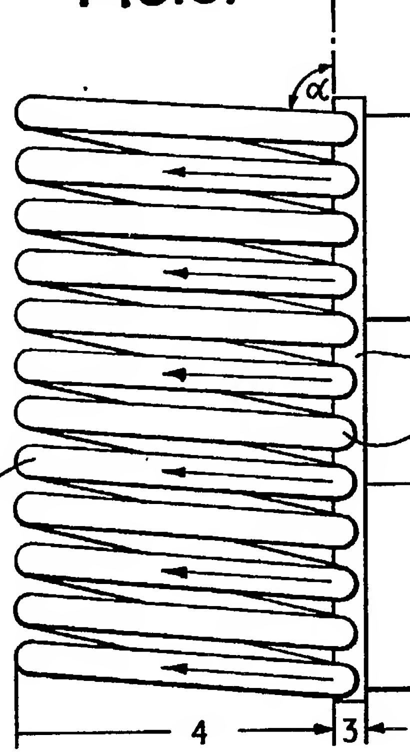
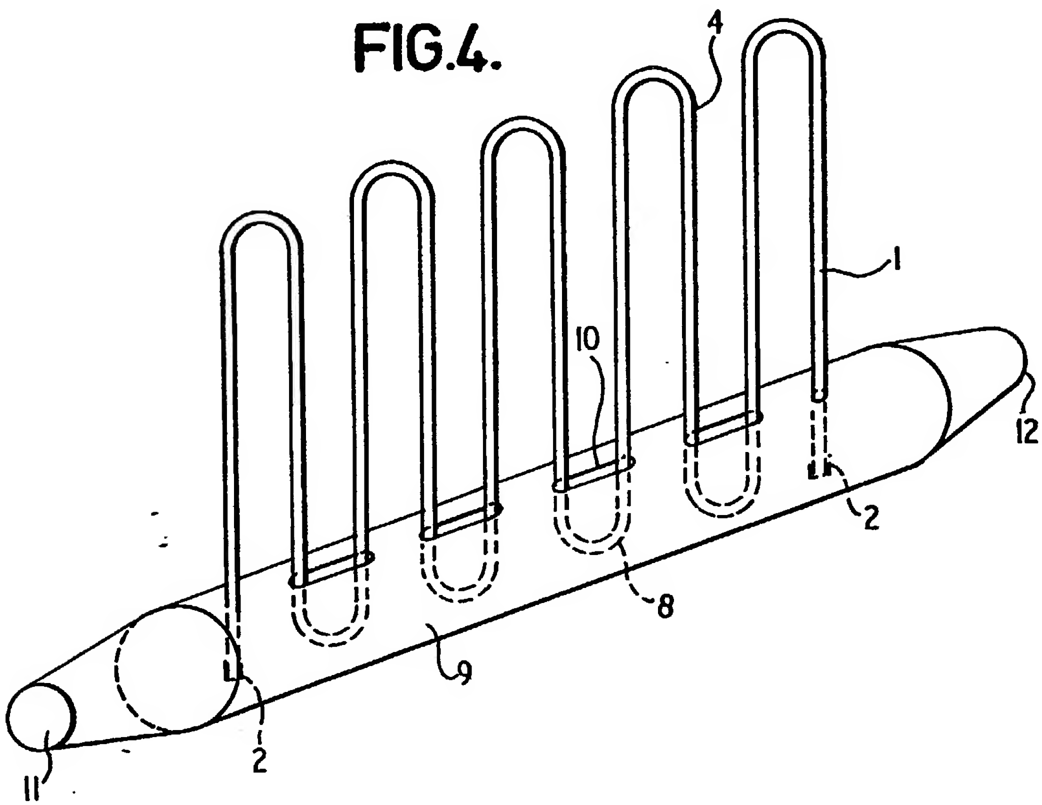


FIG.4.



SPECIFICATION

Device for transporting thermal energy

This invention relates to a device for transporting thermal energy between two places at which different temperatures prevail, which device comprises a sealed tube which is filled with a working medium which (in use of the device) evaporates at the place of higher temperature (heating zone) and condenses at the place of lower temperature (cooling zone), the condensate being transported continuously from the cooling zone back to the heating zone.

Certain gas-tightly closed systems in whose interior a heat carrier is present partly in liquid form and partly as saturated vapour are finding wider and wider technical and industrial applications, more particularly in the field of heat and refrigeration engineering. If heat is supplied to one region of the system, then the heat carrier evaporates there and flows to the colder or cooled region, where it condenses and surrenders its heat of evaporation. If the cooling zone lies above the heating zone, then the condensate will flow back into the heating zone by gravity. Systems in which gravity is utilized for the return of the condensate are called "heat siphons"; systems in which the transport of the condensate is obtained by virtue of capillary forces are called "heat pipes".

The circulation of the heat carrier is caused by the frequently very slight temperature difference between the heating zone and the cooling zone. A higher vapour pressure prevails in the heating zone than in the cooling zone, and this pressure gradient drives the vapour to the colder or cooled region. One substantial advantage of the systems under discussion is that their effective thermal conductivity is greater, by several orders of magnitude, than that of the best metallic conductors. With these systems, heat can be transported counter to gravity. They are simple to handle and easy to assemble, and require no maintenance.

However, the systems referred to require first to be evacuated and thereafter to be filled with a predetermined quantity of a working medium. The system must then be pressure-tightly sealed.

It is an object of the present invention to provide a heat siphon or a heat pipe which can be produced considerably more simply (for a device of given capacity) than the prior-art devices of which we are aware.

According to the present invention, we provide a device for transporting thermal energy between two places at which different temperatures prevail, which device comprises a sealed tube which is filled with a working medium which (in use of the device) evaporates at the place of higher temperature (heating zone) and condenses at the place of lower temperature (cooling zone), the condensate being transported continuously from the cooling zone back to the heating zone, characterised in that the tube is so shaped, in respect of successive portions of its length, that it comprises a plurality of portions extending through the heating zone and a plurality of portions extending through the cooling zone. By virtue of the shaping as just mentioned of an evacuated and filled tube of great length, a plurality of mutually communicating heat siphons or heat pipes can be produced. In this connection it has been discovered, quite unexpectedly, that no drying out of one of the juxtaposed heat pipes or heat siphons occurs, because if there were any tendency towards drying out, the condensation zone of the adjacent liquid-carrying system would spread into the region threatened with drying-out, so that the latter would become filled with liquid. A stable state can thus be attained.

The tube may with particular advantage have a spiral or meander configuration. By this arrangement a device capable of transmitting large quantities of heat can be accommodated in a remarkably small space. This compactness can be enhanced if a plurality of tube portions of meander configuration are arranged one over another. According to an optional feature of the invention, the tube is a seamless drawn and soft-annealed thin-walled copper tube. Another advantageous form of tube is a longitudinally welded and corrugated metal tube. Both a soft annealed thin-walled copper tube and a longitudinally welded and corrugated metal tube can readily be made sufficiently flexible to permit the tube to be wound into virtually any desired shape. Copper, by virtue of its good thermal conductivity, can ensure good heat transfer in both the heating and the cooling zones. The use of a tube which is corrugated also has the advantage that the surface in the region of the heating and cooling zones is enlarged.

A particularly good effect is obtained if the tube portions constituting the heating zone are disposed at a lower level than the tube portions constituting the cooling zone. In this case no further measures need be adopted for returning the condensate, because the latter flows back to the heating zone by gravity. However, it may be advantageous for some applications to provide, in the interior of the tube, capillaries transporting the condensate from the cooling zone to the heating zone. By this means it is even possible to transport the condensate counter to gravity. The advantage is furthermore achieved that the condensate can be distributed uniformly over the entire region of the heating zone by the capillaries, whereby the efficacity of the system can be increased.

If desired, the tube may be so shaped as to comprise turns which are of different length.

If desired, transport zones may be provided between the heating zones and the cooling zones, the pipe portions constituting the transport zones being of a substantially extended aspect and being closely juxtaposed, whereas the pipe portions constituting the heating and cooling zones are fanned.

If it is desired that the present device should be used for heat exchange between a working medium and a massive component, which may be an electronic component, e.g. a thyristor, then, according to a further optional feature of the invention, a beam-shaped element composed of thermally conductive material, placed in thermally conductive contact with the individual adjacent portions of the tube, in the

region of the heating zone or cooling zone, can be employed to connect these portions together, one or more units capable of supplying or dissipating thermal energy being arranged in good thermally conductive contact with the beam-shaped element. By means of the beam-shaped element, which is advantageously of copper in the interest of thermal conductivity, heat exchange between solid bodies and air can be substantially improved. For example, energy liberated by units as just mentioned can be distributed through the beam-shaped element uniformly to the above-mentioned individual adjacent portions of the tube, so that a particularly substantial heat output can be dissipated by this device according to the invention. More particularly in the case of a device employing a corrugated tube having a spiral configuration, its heat-transferring capacity can be increased by providing that the beam-shaped element presents a recess for each of the above-mentioned adjacent portions of the tube, the recessed surface in contact with the tube being adapted to be corrugated contour of the tube. Thus it is possible, e.g., to make recesses in the beam-shaped element by a cutting operation employing a machine tool, or again the beam-shaped element can be produced, with the recesses already present, by casting. The above-mentioned adjacent portions of the tube may be connected to the beam-shaped element by a thermally conductive solder layer. A solder based on copper/silver has been found to be particularly advantageous for this purpose.

According to an optional feature, the beam-shaped element is disposed vertically and portions of the tube are each inclined with respect to the horizontal and are substantially parallel to one another. Due to the inclination of the said portions, which may be individual turns of the tube, the condensate flows back to the heating zone by gravity. The beam-shaped element forms a heating zone when heat is supplied to the flowing medium, though not when heat is withdrawn from the medium. The mode of inclination of the inclined portions of the tube is determined accordingly. Furthermore, when a vertical arrangement is adopted for the beam-shaped element, use can be made of the fact that when a gas is heated there is increased convection by upwardly streaming heated gas (e.g. air). To obtain a good circulation of air over individual turns of the tube, the tube may be so shaped as to comprise turns which are arranged at a predetermined mutual interval.

The tube may for example be of copper, aluminium or stainless steel.

An advantageous further construction in accordance with the invention is characterised in that the tube has turns which are surrounded fluid-tightly in the region of the heating and/or cooling zone by a tank through which (in use of the device) a medium to be cooled or heated flows.

We thus provide a device for transporting thermal energy, or heat exchanger, of small weight but high capacity.

More specifically, the tank may be included in a cooling circuit, and the turns of the tube passed through orifices into its wall and soldered to the wall.

A heat exchange unit can thus be produced which merely requires to be included in a circuit to be cooled.

A device as just described can with particular advantage be used in a motor vehicle cooling system. An advantage obtainable in this case more particularly is a saving of weight of up to 5 kg. Safety can also be improved, because even if the heat pipe should be destroyed the cooling circuit itself may remain liquid-tight, so that a certain cooling effect can still be possible. A cooler according to the invention is particularly suitable for a maintenance-free, i.e., tightly sealed, cooling circuit.

A device as just described can also be employed generally with cooling installations utilising a circulation of cooling medium. This applies not only to the motor vehicles just mentioned, but also the rail-borne vehicles and to stationary cooling installations, e.g., for machinery or dry cooling towers in power generating stations. Another significant application is the recuperation of heat from the earth or the air. Here, in contrast with the cooling installations, a medium to be heated, e.g., the working medium of a heat-pump installation, is passed through the tank past the turns of the tube, and the turns provided outside, in the earth, in the ground water or in the atmosphere, surrender their heat to the flowing medium. The tube used may with particular advantage be a corrugated tube, which is particularly suitable for heat exchange due to its enlarged surface per unit of length. In many fields of application, the flexibility achieved by the corrugation may be advantageous.

The invention will be explained more fully with reference to the accompanying diagrammatic drawings, in which each of the four Figures shows a respective embodiment of the invention.

More particularly, the four figures of the drawings each show a heat transport device which comprises a metal tube 1 which has been given a spiral configuration (Figure 1 or 3) or meander configuration (Figure 2 or 4). The tube 1 is advantageously produced from a copper band, e.g. 0.3 mm thick, which has been bent round into the shape of a slit tube, welded together along the edges of the slit, and corrugated, in one continuous process; however, the tube 1 may instead be a seamless drawn copper tube which has been soft-annealed during a final pass and which is therefore highly flexible.

From the length of tube originally produced, the required length is cut off, and this is sealed pressure-tightly at both ends by means of caps 2. One of the caps 2 affords a pipe connection, not shown, whereby a vacuum pump can be connected to evacuate the tube. After evacuation, the desired working medium is introduced, and the pipe connection is sealed pressure-tightly. The winding or meander-shaping of the tube 1 may be performed either before or after the evacuation and filling of the tube.

In the embodiments of figures 1 and 2, there is a heating zone 3 in the lower region, and a cooling zone 4 in the upper region, so that condensate formed in the cooling zone 4 is transported back to the heating zone 3 by gravity.

During the filling of the shaped tube 1, no special precautions need be taken to ensure that each individual turn is at least partly filled with the working medium, because after the device is taken into service the working medium becomes distributed uniformly among the individual turns. In these embodiments, all the lower lying portions provide the heating zone 3, whereas all the higher portions provide the cooling zone 4. It has thus been possible, in the device of the invention, to obtain a plurality of juxtaposed heat siphons or heat pipes by the use of a single tube 1 which is employed as a heat siphon or heat pipe; this makes possible a considerable saving in costs, and enables the efficiency of a heat pipe or heat siphon to be increased several times in comparison with the prior-art devices which we have had under consideration. In this connection, it has been discovered, entirely unexpectedly, that drying out of a turn of the tube cannot occur, because, if there were any tendency for one turn to dry out, the condensation zone(s) of the adjacent turn(s) would extend into the region of the turn threatened with drying out, so that the condensate would flow back into that turn.

The invention is by no means restricted to heat siphons as represented by the illustrated embodiments; it is also applicable to heat transport systems which operate on the principle of the heat pipe, i.e. systems in which the return of a condensate is effected by capillary forces. In this latter case, however, a capillary structure, e.g., in the form of a synthetic resin network, has to be inserted into the interior of the present tube.

Figure 3 shows a heat transport device constituted by a corrugated copper tube 1 would into the form of a spiral. Heating and cooling zones are again shown at 3 and 4 respectively. The tube 1, as before, is first evacuated and filled to the extent desired with a working medium, and thereafter sealed vacuum-tightly. Then, parallel to the axis of the spiral, a beam-shaped element 5 made of copper, which has a series of recesses 6, one for each turn of the tube 1, is soldered on to the outside of the tube 1. In order that condensate can be returned to the heating zone 3 by gravity, the individual turns of the tube 1 are set at an angle α, which is smaller than 90°, to the axis of the element 5. Heat generators 7, which may be electronic heat generators, e.g. thyristors, are attached in good thermally conductive contact to the element 5. If the device is intended for a situation opposite to that shown in Figure 3, the turns of the tube 1 are set at an angle of slightly more than 90° to the vertical.

The thermal energy liberated by the heat generators 7 is transmitted to the element 5, which in turn, by virtue of its good thermal conductivity, passes it to the individual turns of the tube 1. The liquid working medium present in the region of the heating zone 3 is evaporated by the thermal energy supplied thereto, and the resulting vapour flows (under the prevailing pressure differential) into the region of the cooling zone 4, where it condenses; the condensate flows back to the heating zone 3 by virtue of the inclined arrangement of the individual turns. The cooling in the region of the cooling zone 4 can be improved by a forced convection, produced (e.g.) by a fan, not shown.

If desired, a thermally conductive connection may be provided between the beam-shaped elements 5 of two similar devices according to the invention as shown in Figure 3, so as to form an apparatus suitable for heat exchange between two flowing media. In this case, the cooling zones and heating zones have to be reversed in the second device.

A plurality of devices as shown in Figure 3 may if desired be attached by means of their beam-shaped elements 5 to the outer surface of a pipe in which a medium to be cooled flows.

The device shown in Figure 4 employs a metal tube 1 having a meander-like structure, whose turns 8 are introduced through orifices 10 into a tank 9 (e.g. a tubular tank) and soldered tightly to the wall of the tank. A medium to be cooled, for instance, e.g. water in a motor car engine, can now be supplied and discharged through connecting orifices 11 and 12 provided in the tank 9. In the region of the cooling zone, shown at 4, the thermal energy which is abstracted, from the medium to be cooled, by the evaporation and condensation process taking place within the tube 1, is dissipated by the slipstream or by means of an additional fan, not shown, i.e. the heat is given up from the cooling zone 4 to the air flowing past that zone.

Similar arrangements can be adopted in stationary installations, the necessary air circulation being ensured by fans or taking place through a cooling tower. If design considerations permit, the turns 8 may if desired be disposed generally horizontally, and furthermore may be disposed on both sides of the tank 9.

If the circulating medium (i.e. the working medium) is required to take up heat, e.g. in the removal of heat from ground water, then the tank 9 has to be disposed above the tube 1.

By appropriate dimensioning of the tube surfaces inside the tank and those outside the tank, optimum allowance may be made for the different circumstances in which heat exchange takes place on the gas side and on the liquid side, under the relevant operating conditions.

CLAIMS

1. Device for transporting thermal energy between two places at which different temperatures prevail, which device comprises a sealed tube which is filled with a working medium which (in use of the device) evaporates at the place of higher temperature (heating zone) and condenses at the place of lower temperature (cooling zone), the condensate being transported continuously from the cooling zone back to the heating zone, characterised in that the tube (1) is so shaped, in respect of successive portions of its length, that it comprises a plurality of portions extending through the heating zone and a plurality of portions extending through the cooling zone.

2. Device according to claim 1, characterised in that the tube (1) has a spiral configuration.

3. Device according to claim 1, characterised in that the tube (1) has a meander configuration.

4. Device according to claim 3, characterised in that at least two meanders are arranged one over

another.

5. Device according to any of the preceding claims, characterised in that the tube (1) is a seamless drawn and soft-annealed thin-walled copper tube.

6. Device according to any of claims 1 to 4, characterised in that the tube (1) is a longitudinally welded and corrugated metal tube.

7. Device according to any of the preceding claims, characterised in that the tube portions constituting the heating zone (3) are disposed at a lower level than the tube portions constituting the cooling zone (4).

8. Device according to any of the preceding claims, characterised in that capillaries transporting the condensate from the cooling zone (4) to the heating zone (3) are provided in the interior of the tube.

9. Device according to any of the preceding claims, characterised in that the tube (1) is so shaped as to comprise turns which are of different length.

10. Device according to any of the preceding claims, characterised in that transport zones occur between the heating zones (3) and the cooling zones (4), the pipe portions constituting the transport zones being of a substantially extended aspect and being closely juxtaposed, whereas the pipe portions constituting the heating and cooling zones (3, 4) are fanned.

11. Device according to claim 1, substantially as described with reference to Figure 1 or 2 of the accompanying drawings.

12. Device according to any of claims 1 to 10, characterised in that, in the region of the heating zone (3) or of the cooling zone (4), a beam-shaped element (5) composed of thermally conductive material, placed in thermally conductive contact with the individual adjacent portions of the tube (1), connects these portions together, one or more units (7) capable of supplying or dissipating thermal energy being arranged in good thermally conductive contact with the beam-shaped element (5).

13. Device according to claim 12, employing a corrugated tube (1) having a spiral configuration, characterised in that the beam-shaped element (5) presents a recess (6) for each of the said adjacent portions of the tube (1), the recessed surface in contact with the tube (1) being adapted to the corrugated contour of the tube (1).

14. Device according to claim 12 or 13, characterised in that the beam-shaped element (5) is of copper.

15. Device according to claim 12, 13, or 14, characterised in that the said adjacent portions of the tube are connected to the beam-shaped element (5) by a thermally conductive solder layer.

16. Device according to claim 12, 13, 14 or 15, characterised in that the beam-shaped element (5) is disposed vertically and portions of the tube are each inclined with respect to the horizontal and are substantially parallel to one another.

17. Device according to any of claims 12 to 16, characterised in that the tube (1) is so shaped as to comprise turns which are arranged at a predetermined mutual interval.

18. Device according to any of claims 12 to 17, characterised in that the tube (1) is of copper, aluminium or stainless steel.

19. Device according to claim 12, substantially as described with reference to Figure 3 of the accompanying drawings.

20. Device according to any of claims 1 to 10, characterised in that the tube (1) has turns which are surrounded fluid-tightly in the region of the heating and/or cooling zone (3, 4) by a tank (9) through which (in use of the device) a medium to be cooled or heated flows.

21. Device according to claim 20, characterised in that the tank (9) is included in a cooling circuit and the turns of the tube (1) are passed through orifices (10) into its wall and soldered to the wall.

22. A device according to claim 20 or 21, when used in a cooling installation utilising a circulation of cooling medium.

23. A device according to claim 20 or 21, when used in a motor vehicle cooling system.

24. A device according to claim 20 or 21, when used for recuperating heat from the earth or the air.

25. A device according to claim 20, substantially as described with reference to Figure 4 of the accompanying drawings.

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